USE OF SEWAGE SLUDGE COMPOST FOR SOIL IMPROVEMENT AND PLANT GROWTH

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ABSTRACT

This report discusses the properties and uses of sewage sludge compost for soil improvement and for plant growth including (1) establishment, maintenance, and production of turfgrass and sod, (2) use in vegetable gardens, (3) production of field crops and forage grasses, (4) use on nursery crops and ornamentals, and (5) reclamation and revegetation of disturbed lands. Recommendations are provided as to time, methods, and rates of compost application for different soils and management practices.

KEYWORDS: Compost, compost application rates, field crops, land reclamation, nursery crops and ornamentals, plant growth, sewage sludge, sod production, soil improvement, turfgrass.

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USE OF SEWAGE SLUDGE COMPOST FOR SOIL IMPROVEMENT AND PLANT GROWTH

By S. B. Hornick, J. J. Murray, R. L. Chaney, L. J. Sikora, J. F. Parr, W. D. Burge, G. B. Willson, and C. F. Tester[1/]

INTRODUCTION

The ancient practice of composting converts organic wastes into a humuslike product that can be used as a soil amendment. This report describes research on compost made from undigested sewage sludge generated in the Washington, D.C., metropolitan area and from wood chips. This sludge and wood chip mixture was composted by the Beltsville Aerated Pile Method developed by the U.S. Department of Agriculture at Beltsville, Md., in cooperation with the Maryland Environmental Service and the U.S. Environmental Protection Agency. This method yields a stabilized product as a result of the action of aerobic micro-organisms. As the material in the sludge decomposes, the compost becomes heated to temperatures in the pasteurization range of 55°-70° C, which destroy enteric pathogenic organisms. The end result is a humuslike material that can be used beneficially as a soil conditioner and as a source of plant nutrients. It is essentially odorless and free of enteric pathogens.

During this research, the following limits on the quality of the compost, on a dry weight basis, were determined:

	Less than --
	Percent
Nitrogen	1.5
Phosphorus	2.0
Potassium	.2
Iron	4.0
	Ppm
Zinc	1,250
Copper	500
Cadmium	12.5
Nickel	200
Lead	500
Mercury	5

1/ Agricultural Environmental Quality Institute, except J. J. Murray, who is with Plant Genetics and Germplasm Institute, Beltsville Agricultural Research Center-West, Beltsville, Md 20705.

The cadmium-to-zinc ratio was less than 1.5 percent, chlorinated hydrocarbons were less than 5 ppm each, and alkalinity was greater than 10 percent as calcium carbonate. Beneficial results cannot be assured for sewage sludge composts of greatly different composition from that listed here.

GENERAL USES, PROPERTIES, AND PRECAUTIONS

The compost produced by the Beltsville method can be safely used as a fertilizer or soil conditioner where food-chain, root, and leafy vegetable crops are grown. Sludge compost can be utilized advantageously in potting mixes, for agronomic crops, on lawns, and as a mulch. It can also be used as a topsoil substitute for land reclamation and public works projects, for turfgrass production, for nursery production of trees and ornamental plants, on golf courses and cemeteries, for revegetation of disturbed lands (e.g., from surface mining), and for landscaping of parks and around public buildings.

The application of sludge compost at fertilizer rates (i.e., the nitrogen requirement of the crop) to marginal soils can produce significantly higher yields than commercial fertilizers applied alone at the same nitrogen level. Higher yields are attributed to an improvement in soil physical properties by the compost. Sludge compost is known to improve soil physical properties, as evidenced by enhanced aggregation, increased soil aeration, lower bulk density, less surface crusting, and increased water infiltration, water content, and water retention. Sludge compost added to sandy soils will increase the moisture available to the plant and reduce the need for irrigation. In heavy textured clay soils, the added organic matter will increase the soil's permeability to water and air, increase water infiltration into the profile, and thereby minimize surface runoff. The soil also will have a greater water storage capacity. Addition of sludge compost to clay soils has also been shown to reduce compaction (i.e., lower the bulk density) and to increase root development. Since the compost contains a minimum of 10 percent limestone, it also serves as a liming material on slightly acid soils.

Sludge compost, like composted manure, is hygienically and environmentally safe if it is used properly, but it can become a hazardous nuisance if mismanaged. Do not leave it in unprotected piles that might become a play area for children or where pets might wander. Keep it away from all surface water, and do not pile it near wells or other water supplies. It should be washed off all fruits and vegetables before they are consumed.

USE ON TURFGRASSES

Composted sewage sludge can be used economically and beneficially in turfgrass production for various areas, including homelawns, parks, institutional grounds, athletic fields, golf courses, and roadsides. It can also be used in the production of cultivated sod. The benefits from utilizing compost are derived from its content of plant nutrients, organic matter, and liming properties. On many soils with poor physical properties, compost used correctly will produce better turfgrass than chemical fertilizers. Organic matter in the compost, approximately 50 percent by weight, improves the physical

condition of the soil, which in turn improves plant growth. The use of compost as a source of organic matter takes on added significance as more marginal lands are being used for construction of homes and other developments and as good topsoil becomes increasingly expensive.

The plant nutrient content of composted sludge, especially its nitrogen content, and the rate of mineralization are very important when compost is utilized in turfgrass production. Nitrogen affects the rate of turfgrass growth more than other nutrients. Unlike the production of many crops, maximum growth or production of vegetative material in turfgrass production is generally undesirable. The desirable rate of growth is one that is sufficient to maintain a healthy, uniform turf during the growing season without excessive production of vegetation.

The chemical composition of composted sludge is variable. The nitrogen, phosphorus, and potassium content generally ranges from 1 to 1.5, 1.5 to 2, and less than 0.2 percent, respectively. Mineralization is slow with nutrients being released and available for plant growth over a relatively long period. Compost contains approximately 10 percent lime and will increase the pH of acid soils. However, on very acid soils (pH below 4.5), additional lime may be needed to increase the pH to 6.5 if less than 1,600 pounds per 1,000 square feet of compost are used. Application rates to supply the nitrogen requirement will also supply sufficient levels of all other essential nutrients for growth of turfgrass, except potassium. Supplemental potash should be added according to soil test results, or at least 120 pounds per acre.

Composted sludge can be used in turfgrass production as (1) a soil amendment for the establishment of turfgrass, (2) a fertilizer source for maintenance of established turfgrass, and (3) a soil amendment or growth medium for commercial turfgrass production.

Establishment

Establishment of turfgrass from seed or sod can be significantly increased on many soils by using composted sludge principally as a soil conditioner. When the compost is incorporated with the top 5-6 inches of the soil or is applied as a mulch to the soil surface before or after seeding, seedling establishment is more rapid than with conventional fertilizer practices. Best results for germination, establishment, and initial growth rate of turfgrass are obtained with applications of 2,000-6,000 pounds per 1,000 square feet (wet weight equivalent to 40 percent moisture[2/]). The lower rate is generally used on fertile soils and the higher rate on sandy soils or subsoils low in organic matter. These rates will provide sufficient nitrogen and phosphorus for optimum plant growth. Potassium must be added if the soil is naturally low in this element. The potassium fertility level of a soil can be verified by a soil test. Additions of less than 2,000 pounds per 1,000 square feet are beneficial but should be supplemented with commercial nitrogen and potassium fertilizers. Where com-

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2/ For all practical purposes, 1 cubic yard of screened compost at 40 percent moisture will weigh about 1,000 pounds and will cover a 1,000-square-foot area to a depth of one-third inch.

post applications are based on the nutrient requirements of the turfgrass, rather uniform and favorable growth rates can be expected for 5-6 months after seeding or sodding. Excessive growth occurs with additions greater than 6,000 pounds even on infertile soils.

Compost applied at 600-700 pounds per 1,000 square feet to the soil surface as a mulch before or after seeding can markedly increase the rate of establishment of cool-season grasses. The greatest benefits from its use as a mulch have been on late fall or early spring seedings when air temperatures are relatively cool. When used as a mulch with small seeded grasses, such as Kentucky bluegrass and bentgrass, the compost should be applied before seeding. With larger seeded grasses, such as tall fescue, red fescue, and perennial ryegrass, the compost mulch should be applied uniformly after seeding.

Root growth of conventionally produced sod is increased when the sod is laid on soil previously amended with compost. Applications of 2,000-4,000 pounds per 1,000 square feet, depending on the soil and incorporated to a depth of 4-6 inches, will significantly increase root growth and development and provide near optimum growth for 2-4 months after the sod is laid. Root growth is not increased appreciably with higher compost rates; however, excessive grass growth can be expected with rates higher than 6,000 pounds per 1,000 square feet.

Maintenance

Composted sewage sludge can substitute for conventional fertilizer in the maintenance of established turfgrasses. The extent to which compost can be used to supply the total nitrogen requirement depends on the maintenance level desired. For turf under a low-to-moderate maintenance level, compost can be used to supply the total nitrogen requirement. For higher maintained or higher quality turf, compost can be used to supply a part of the nitrogen requirement, with the additional nitrogen supplied from other sources.

The response of tall fescue and Kentucky bluegrass is best with applications of 800 pounds per 1,000 square feet in the fall or split applications of 400 pounds per 1,000 square feet in the fall and again in the spring (March). These treatments will provide acceptable turfgrass quality for general-purpose turf and most homelawns. However, higher quality turf can be obtained by applying compost in the fall and winter at rates that would supply one-half of the total nitrogen requirement. A water-soluble source of nitrogen would then be applied when needed for added color, probably during late spring or early summer. Growth response of cool-season grasses to compost applications can usually be detected within 72 hours after it is applied. Response is poor during periods of high air temperatures. Low rates of application in the summer have also increased dollar spot disease, and applications in late spring or early summer have increased leaf spot disease on Kentucky bluegrass. The use of compost on close cut, highly maintained turf, such as golf-course greens and tees, may be objectionable because of a black residue.

Sod Production

The greatest potential use of compost in the turfgrass industry is probably in commercial sod production. If compost is managed properly, large quantities

could be used on a relatively small land area. It can be used in sod production as a soil amendment, as discussed under establishment of turfgrasses, or as a growth medium.

When used as a soil amendment, 3,000-6,000 wet pounds per 1,000 square feet (approximately 65-130 wet tons per acre) incorporated to a depth of 4-6 inches will provide good plant growth. Incorporating the compost is essential if irrigation is not practiced. Further research is needed to evaluate the optimum usage of compost under different production practices.

Composted sewage sludge is an ideal growth medium for most turfgrasses. The only essential plant nutrient that has to be added is potassium. Kentucky bluegrass-red fescue and tall fescue-Kentucky bluegrass mixtures seeded into a 2- to 6-inch layer (6,000-18,000 wet pounds per 1,000 square feet) of compost on the soil surface can produce a harvestable sod within 7 months after fall seeding compared with 12-18 months normally required when compost is not used. When seeding into a layer of compost on the soil surface, irrigate to leach salts and prevent drying of the upper part. Although frequent mowing is required, the total number of mowings would be about the same as with conventional sod production because the sod can be harvested sooner. Other advantages of surface applications are that little or no herbicides and commercial fertilizers are required. Moreover, compost sod weighs about 30-40 percent less than mineral soil sod.

USE ON VEGETABLE CROPS

Compost can be used in vegetable gardens as a fertilizer and a soil conditioner. Because the high temperatures achieved during composting destroy enteric pathogens, vegetables eaten uncooked may be grown the same year that the compost is applied. Also, since the composition of the distributed product is monitored to meet State regulations, all types of crops may be grown safely for human consumption. As in other vegetable gardens, leafy vegetables should be washed to remove soil and any pesticide residues.

Compost should be applied at rates to supply the nitrogen required by the plants to be grown. Information on specific crop fertilizer requirements for gardens can be obtained through the local cooperative extension agent. If the compost contains 1.5 percent nitrogen, a 1/2-inch layer of compost or 1,500 pounds per 1,000 square feet of compost will supply approximately 60 pounds of nitrogen. After application, the compost should be thoroughly mixed with the top 4-6 inches of soil. Compost should be applied 1-2 weeks before planting any vegetables to prevent injury from soluble salts. An inch of compost or 3,000 pounds per 1,000 square feet tilled into most gardens will supply enough nitrogen for nearly any crop; excessive nitrogen from any source can delay and reduce the fruiting of tomato and other crops. Compost contains organic nitrogen that becomes available over a period of time and acts much like a slow release nitrogen fertilizer. Thus, the compost application should be reduced to a one-half inch in subsequent gardening years since some residual nitrogen is supplied from previous compost applications.

Compost usually provides all the nitrogen and phosphorus that crops generally need. However, since many gardens are low in potassium (potash), supple-

menting compost with a potash fertilizer may increase the yield of fruit and root crops. The compost contains enough lime to make most gardens with slightly acid soils reach optimum soil pH levels. If soil tests show the pH to be below 6.5-7.0 after applying the compost, some limestone should be applied. Soil testing can identify the need for supplemental potash and will specify the amount of lime to apply. Contact the county Cooperative Extension Service for information on obtaining a soil test. After several years of compost use, the benefits of additional organic matter are small, and regular fertilizers can be used since they are as effective as additions of compost for supplying plant nutrients.

USE ON FIELD CROPS

When sewage sludge compost is used as a fertilizer as well as a soil conditioner for agronomic row crops or pasture, yearly compost application rates should be determined by the nitrogen or phosphorus requirement of the specific crop to be grown. This information can be obtained from a local cooperative extension agent. For example, an oat variety requiring only 40 pounds of nitrogen per acre would need 1,000 pounds per 1,000 square feet (21.5 tons per acre) of sludge compost as the soil amendment. A corn variety requiring 150 pounds of nitrogen per acre would need 3,800 pounds per 1,000 square feet (83 tons per acre) of sludge compost. A general rule of thumb to calculate the nitrogen supplying power of sludge compost containing 1.5 percent nitrogen is that 1 ton of compost contains about 1.9 pounds of available nitrogen on a wet weight basis. This assumes that 10 percent of the nitrogen in the compost is available to the crop the first year. Compost application rates for field crops are given in table 1. To plant legumes the same year the compost is applied is not considered a good practice, because the nitrogen released from the compost will initially reduce the quantity supplied by the legume. Moreover, since most legumes do not need nitrogen fertilizer, it is an inefficient use of the nitrogen. Compost applications in the field can be made by using a calibrated manure spreader.

Because the compost also contains 2 percent phosphorus, supplemental phosphorus fertilization is not necessary when compost is applied according to the nitrogen requirement of the crop. Since the compost contains only 0.2 percent potassium, it may be necessary to apply supplemental potash to such crops as corn.

Compost also contains a minimum of 10 percent limestone; however, on very acid soils, that is, those with a pH below 4.5, 1-2 tons of limestone may be needed if less than 1,600 pounds per 1,000 square feet (35 tons per acre) of compost are added. In general, the best management practice is to maintain soil pH at 6.5-7.0. Periodic soil testing and pH monitoring are advisable to insure proper soil fertility. These services can be obtained through the Cooperative Extension Service.

USE ON FORAGE GRASSES

Compost can be used successfully to establish and maintain forage grasses. For establishment, 4,000-7,000 pounds per 1,000 square feet should be

thoroughly incorporated with the top 6 inches of soil. The lower rate should be used on rather fertile or already productive soils and higher rates on unproductive soils. Additions of compost at the preceding rates should produce a rapid rate of growth. Later applications of one-half pound per 1,000 square feet (25 pounds per acre) of a soluble nitrogen fertilizer will be needed to maintain a high rate of growth.

To maintain the pasture after the first year, apply compost after the grass is mowed or cut. A rate of 1,000-1,300 pounds per 1,000 square feet should be sufficient to maintain growth and produce quality forage. Animals can be allowed to graze after regrowth has occurred. After repeated applications of sludge compost (5-10 years), a substantial amount of compost probably will have accumulated on the surface from topdressing. If so, the pasture should be renovated by tilling the compost into the soil. Tilling and replanting best utilize the soil conditioning properties of the compost and minimize ingestion of the compost by the animals while grazing.

USE ON NURSERY CROPS AND ORNAMENTALS

Mixing compost in nursery soils and soils where plantings of trees and shrubs are to be made can improve soil fertility, pH, soil structure, and the water-holding capacity. Compost can be used very effectively for growing many nursery crops and ornamentals with applications of 1,900-7,000 pounds per 1,000 square feet incorporated with the surface 6-9 inches of soil.

Compost used for these purposes has two important limitations. It contains limestone (over 10 percent by weight) and at high rates makes soils calcareous (about pH 7.3). This high pH interferes with the growth of the following plants: Andromeda, azalea, blueberry, Japanese holly, Leucothoe, mountain-laurel, pin oak, rhododendron, scarlet oak, and sourwood. The other limitation is soluble salts. Rates of over 2,000 pounds per 1,000 square feet may temporarily injure plants and slow seed germination if the soil is not thoroughly watered before planting or seeding.

In subsequent years, compost-amended soils may require supplemental applications of nitrogen and potassium. Nitrogen can be applied by using organic wastes or commercial fertilizers.

USE IN POTTING MIXES

Sludge compost can be used effectively in preparing potting mixes to grow transplants for ornamental, garden, or commercial purposes. Here, too, compost supplies organic matter, calcium, lime, magnesium, phosphorus, potassium, and slow-release nitrogen, as well as fertilizer levels of the microelements (boron, copper, iron, manganese, molybdenum, and zinc) for plants. Effective potting mixes have been prepared, by volume, from sludge compost + peat moss + vermiculite (1:1:1), compost + peat + sand (1:1:1), and compost + infertile loamy subsoil (1:1).

Because sludge compost may supply levels of soluble salts too high for potting mixes, compost-based mixes must be leached before use in closed pots.

Pots with drainage are usually watered to excess (tapwater poured on surface of mix in pot) and allowed to drain. By leaching or wetting and draining the pots in this manner, the potential for salt injury of plants can be decreased. Use of compost at greater than 50 percent by volume is wasteful of the nutrients and is not advisable. After several months' growth, supplemental nitrogen fertilizer may be required depending on the amount of growth, amount of compost in the mix, and size of the pot.

USE FOR RECLAMATION OF DISTURBED AND MARGINAL LANDS

Applying composted sludge can aid significantly in the revegetation and reclamation of lands disturbed by surface mining, removal of topsoil, and excavation of gravel deposits. On these lands the establishment and growth of plants are difficult because of (1) extremely low pH, (2) extreme droughtiness from lack of organic matter, (3) very high surface temperatures, (4) lack of nutrients, and (5) very poor soil physical conditions. Research by the Department of Agriculture has shown that through the proper use of sludge compost and dolomitic limestone, a wide variety of agronomic crops can be grown on such lands. With proper management, disturbed lands can be reclaimed in a surprisingly short time. Often in reclamation, the use of compost is cheaper and plant growth better than with commercial fertilizers.

Compost applications for marginal lands should be based on soil characteristics and the cover crop to be grown. For disturbed soils, up to 9,200 pounds per 1,000 square feet (200 wet tons per acre) could be applied, with even higher rates where the compost is mixed with more than 6 inches of surface soil and where ground-water contamination is not a potential problem (e.g., if the watershed has essentially no other nitrogen inputs and any resulting contamination would be small, temporary, or both). Since compost functions as a slow release nitrogen fertilizer, a heavy single application of compost could supply the fertilizer requirements for several seasons. Research has shown that on very droughty or acid soils, the deeper the compost is incorporated with the soil, the better are the crop yields. Special equipment may be required for deep placement of the compost.

In general, the establishment of grasses on disturbed or marginal lands has been best with a fall application of sludge compost and subsequent seeding. For both grassland and agronomic crops, the compost should be thoroughly plowed and disked into the soil before the crop is planted. On acid soils, with crops requiring less than 1,600 pounds per 1,000 square feet (35 wet tons per acre) of sludge compost for their nitrogen requirement, 1-2 tons per acre of dolomitic limestone may be needed. On soils where the pH is lower than 4.5, more lime may be necessary for maximum crop yields.

Compost can be used beneficially as a mulch after conservation seedings. With the wood chips present (unscreened), it will more effectively control erosion and water loss by evaporation. From 300-700 pounds per 1,000 square feet can be applied.

Table 1.--Various uses and application rates of sewage sludge compost to achieve fertilizer benefits and soil improvement

Use	Compost per 1,000 square feet[1/]	Remarks
	Pounds	
Turfgrasses:		
Establishment:		
Soil incorporated	2,000-6,000	Incorporate with top 4-6 inches of soil. Use lower rate on relatively fertile soil and higher rate on infertile soil.
Surface mulch	600-700	Broadcast uniformly on surface before seeding small seeded species (bluegrass) or after seeding large seeded species (fescues).[2/]
Maintenance	400-800	Broadcast uniformly on surface. On cool-season grasses apply higher rate in fall or lower rate in fall and again in early spring.
Sod production when--		
Incorporated with soil	3,000-6,000	Incorporate with top 4-6 inches of soil.
Unincorporated with soil	6,000-18,000	Apply uniformly to surface. Irrigate for germination and establishment.
Vegetable crops:		
Establishment	1,000-3,000	Rototill into surface 1-2 weeks before planting or in previous fall. Do not exceed recommended crop nitrogen rate.
Maintenance	1,000	Rate is for years after initial garden establishment. Rototill into surface 1-2 weeks before planting or in previous fall.
Field crops:		
Barley, oats, rye, wheat	1,000-1,300	Incorporate into soil 1-2 weeks before planting or in previous fall.
Corn	3,000-3,800	Incorporate into soil 1-2 weeks before planting. Supplemental potash may be required depending on soil test.
Legumes[3/]	---	Legumes can be grown in rotation with corn, oats, or other nitrogen-requiring crops.

See footnotes at end of table.

Table 1.--Various uses and application rates of sewage sludge compost to achieve fertilizer benefits and soil improvement--Continued

Use	Compost per 1,000 square feet[1/]	Remarks
	Pounds	
Forage grasses:		
Establishment	4,000-7,000	Incorporate with top 4-6 inches of soil. Use lower rate on relatively fertile soil and higher rate on infertile soil. Supplement during first year's growth with 1/2 pound per 1,000 square feet (25 pounds per acre) of soluble nitrogen fertilizer when needed.
Maintenance	1,000-1,300	Broadcast uniformly on surface in fall or early spring 1 year after incorporated application.
Nursery crops and ornamentals (shrubs and trees):		
Establishment	1,900-7,000	Incorporate with top 6-8 inches of soil. Do not use where acid-soil plants (azalea, rhododendron, etc.) are to be grown.
Maintenance	200-500	Broadcast uniformly on surface soil. Can be worked into soil or used as a mulch.
Potting mixes	Equal ratio of material[4/]	Thoroughly water and drain mixes several times before planting to prevent salt injury to plants.
Reclamation:		
Conservation planting	Up to 9,200	Incorporate with top 6 inches of soil. Use maximum rate only where excessive growth for several months following establishment is desirable. For each inch beyond 6 inches of incorporation, add 1,000 pounds per 1,000 square feet on soils where ground-water nitrogen will not be increased.
Mulch	300-700	Broadcast screened or unscreened compost uniformly on surface after seeding; unscreened is more effective.

1/ 1,500 pounds per 1,000 square feet is equal to 1/2 inch of compost per 1,000 square feet or 33 wet tons per acre based on 40 percent moisture content and 1/2-inch mesh-screened material.

2/ See p. 4.

3/ Legumes, such as alfalfa and soybeans, do not need all the nitrogen fertilizer supplied by the compost. Maximum benefit of compost as a fertilier can be realized by growing legumes in rotation.

4/ See p. 7.

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